Two Positive Charges Immersed in a Plasma May Attract Each Other

Giovanni Lapenta and Gian L. Delzanno (T-15); ***lapenta@lanl.gov***

We recently made a new discovery that two positively charged dust particles immersed in a plasma and emitting electrons can attract each other. A fundamental knowledge of physics since ancient times is that charges of opposite polarity repel each other. Of course, we are not proposing to violate this. But if two positively charged particles are immersed in a plasma and if they emit electrons due to photoemission, thermionic emission or secondary emission, we propose that attraction is possible.

We have recently published this discovery in *Physical Review Letters* [1]. We have originally discovered the process by simulating the charging of dust particles with a first principles kinetic plasma simulation code. The code describes the evolution of the ions and electrons of the system and their interaction with the dust particle self-consistently with the evolution of the electrostatic field. We have subsequently developed a theory to explain the process. The fundamental mechanism responsible for the attraction is provided by the plasma mediating the interaction between the dust grains. While in absence of emissions the two dust particles would repel each other, the presence of emitted electrons mediates an attraction force.

Our new discovery is of considerable practical relevance as it provides a novel mechanism for the attraction of dust particles in a plasma. This mechanism is relevant for laboratory experiments concerning for example complex plasma crystals, but is even more important for astrophysical applications, such as the collapse of molecular clouds to form solar systems.

Figure 1— ***"Pillars of creation" (courtesy of the Hubble Space Telescope).***

Solar systems are generally believed to form from the gravitational collapse of clouds of dust and ionized gasses, called nebulae. But an issue still defies our understanding: the presence of charges on the collapsing dust particles would hinder and even stop the process of gravitational collapse. The issue presents a formidable challenge to the astrophysicists. The clouds of gas, plasma, and dust that exist prior to the formation of solar systems are often illuminated by nearby young stars just formed in other parts of the clouds. The famous picture (Fig. 1) from Hubble Space Telescope of the so-called "pillars of creation" in the Eagle nebula is an example of such a system.

Light from the stars induces a positive charge on the dust particles through the process of photoemission, resulting in a repulsive force among them. How can a nebula collapse under such repulsive force? Current theories are at a loss to fully resolve this issue. We believe our recent discovery of an attraction potential among similarly charged dust particles could resolve the issue.

We have started a new research effort along this promising line of investigation. We have built a new 3D hybrid, particle-particle, particle-mesh (PPPM) numerical code to study the collapse of a system of interacting dust particles, gasses, and magnetic fields. When particles are simply neutral, the system collapses due to self-gravitation (the so-called Jeans instability). If particles are charged, electrostatic repulsion can impede the gravitational collapse. However, if particles are charged but the interaction potential has the form of the attractive potential well that we discovered, the system can collapse again.

Figure 2 demonstrates the conclusions described above. In Fig. 2a, we show the long-term evolution of a numerical simulation of a system of dust grains that interact through gravitation alone. An accretion disk is formed by gravitational interaction. Figure 2b, instead, considers the case of particles that besides gravitational attraction are also affected by the well known electrostatic repulsion due to their positive charges. Clearly, the gravitational collapse is impeded. But Fig. 2c shows a simulation with our new attractive force among dust particles (alongside the standard gravitational model) proving that gravitational collapse is indeed possible.

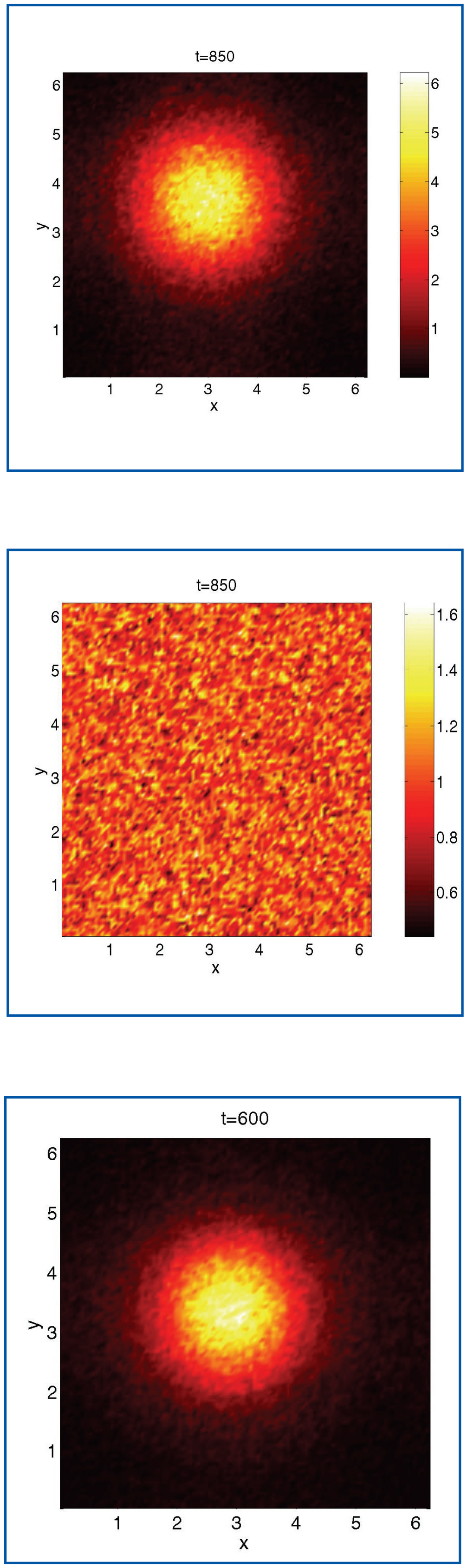

***Figure 2—* Simulations of gravitational collapse in presence of (a) gravity alone, (b) gravity and electrostatic repulsion, and (c) gravity and the new model of interaction described here.**

[1] G.L. Delzanno, G. Lapenta, M. Rosenberg, "Attractive Potential Around a Thermionically Emitting Microparticle," *Phys. Rev. Lett.* **92**, 3 (2004), pp. 350021–350024.